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Modular Coordination

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Modular coordination is the term given to a new procedure for integrating the size of building components so that their assembly may be simplified. It is the first change in measuring for the building industry since the inch and foot were established in uniform lengths by international agreement and became common units of measurement.

For an industry to devise a new unit of measure is not unusual. Many years ago, land sub-dividers found the inch and foot too small for convenience or accuracy and developed the rod, the chain and the mile as multiples of the smaller units. Similarly the building industry is now finding the inch and its fractions too small for common use and requires a new unit in order to coordinate conveniently the many dimensional parts of a building with accuracy.

The new unit is called the module. Its length is 4 inches, or 10 centimeters in the metric system, as established by standards institutions in Canada, United States, United Kingdom*, Norway, Sweden, Denmark, Russia, Poland, Belgium, France, Italy, Netherlands, Brazil and Germany**.

The Building Process

Traditionally, building components have been made on the site from local materials, hewn by hand to fit their required position in the structure. Materials were those which could be worked with hand tools into sizes that could be placed into the structure by a craftsman using only the crudest of machinery. Through his skill and ingenuity components were fitted together and secured in place to form walls, floors, and roofs; within the spaces thus created, furnishings and mechanical equipment were put into place.

With the Industrial Revolution came machines to reduce much of the handiwork in building and improved transportation to facilitate trade and provide a variety of materials. Manufacturers and suppliers of building materials joined the contractor in assuming responsibility for the erection of buildings, while the architect, formerly the 'master builder', concentrated on planning, designing, and coordinating the building process.

Wherever possible, changes are required to simplify building. To build is still to add one component to another. If components were of soft material like plasticene they could easily be cut and changed in shape and fitted together by easy manipulation. But this is not the case. Modern building materials are durable and hard. Some may be hand sawn with metal saws; others require specialized equipment. Glass block, double insulating glass, porcelain glazed sheet metal, metal windows, and mechanical equipment cannot be changed at all in shape after initial manufacture. To combine modern building materials under these restrictive conditions requires newer techniques than those of the traditional craftsman.

At the present time, building components are assembled either with or without careful pre-planning. In neither method are standard, machine-made component units used exclusively. Without assembly planning, the traditional cut-and-fit procedure takes dominant machine-made components, such as windows and doors which cannot easily be reshaped on the building site, and adds to them others such as brick or wood siding which can be cut. This method is common in light construction where the variety of components is small and those materials cut and wasted are relatively inexpensive.

In assembly planning, drawings are made of the whole building in plan elevation and section, followed by detail drawings of the component parts, according to manufacturers' catalogue information on size and shape. In spite of the wide range of sizes offered by manufacturers, it is not possible to obtain many components which can be integrated easily because there is no over-all pattern relating the dimensions. Thus dominant components, perhaps those most frequently occur-

*yet to be published.
**for interior work of a building only.

ring in the building or the most expensive to obtain in special sizes, are selected from the catalogue; all other components are then established in size on the drawings so that they can be manufactured as required. This planning procedure is essential for large projects because of the necessity of fitting together not only the components for the structure but also the heating and ventilating, plumbing, electrical, and other mechanical equipment. It does result in less cutting and reshaping on the site, but much time is spent in selecting from the catalogues those few components which do coordinate in size and in preparing precision drawings for the shop manufacture of the special sizes.

In the first method, time and material are wasted in cutting and fitting on the site where the waste is readily seen; in the second method, time is wasted in offices and in the efficient operation of machines making wide ranges and special sizes of components. Both building methods are handicapped by the waste resulting from the uncoordinated dimensions of the components.

A Coordinating Dimension for All Components

In selecting a dimension which can be used to coordinate the sizes of all components likely to be used in every type of building, attempts have been made to determine the dimension common to the majority. Unfortunately, because of the vast number of existing sizes, it has not been easy to find a common denominator. The dimension must be small enough to permit sufficient variation in total sizes; if 1 foot is selected, then doors would be 2, 3, or 4 feet, and walls 1 or 2 feet thick. These excessive totals or multiples of the coordinating dimension would be wasteful of material and make economical planning impossible. On the other hand, if the dimension is too small, such as 1 inch, then there is the possibility of as great a variety of sizes for the machine to make as now exists.

From the results of studies in different parts of the world, the dimension of 4 inches, and in countries using the metric system 10 centimeters, has been found most satisfactory. Thus a coordinating unit of measurement has been accepted which may be repeated in the sizes of all building components; the name for this unit is the standard building *Module*.

The word module comes from the Latin, modulus, meaning measure. Since 'module' does not denote a size in terms of a common unit of measurement, its use when applied to coordination in building has led to much confusion. As previously shown, the basis for coordination must be an agreed denominator for the sizes of building components in inches or centimeters. Manufacturers may advertise 'modular' desks, cabinets, and other fitments, which by themselves fit together because of some repeated measurement, as do children's blocks or the pieces in the game of dominoes, but the products do not bear any dimensional relationship to the other components in a building.

In establishing the building module as 4 inches, the possibility of dimensions other than simple multiples is not eliminated, because either custom or manufacturing and assembly methods may require that a component have a dimension smaller than the module in one or more dimensions. For these components to be useful modular size, two or more components are joined together to total a dimension which is a multiple of 4 inches. The most common example of this type of component is the clay brick. Owing to the manufacturing problems of firing large volumes of clay to a uniform dimension in the kiln, the height of the brick is kept less than 4 inches. As the next higher modular dimension is eight, bricks are sized so that three bricks, with their joints, will equal 8 inches, the modular height of each brick being 2⅔ inches.

Modular Components

Having once set the standard building module, a uniform procedure may be laid down for any manufacturer to follow in order that the different components, when added together in the building, will total modular dimensions. The procedure recognizes three facts: (1) that between all components there is a space or joint, (2) that the joint may vary from the 'best' size to a practicable maximum or minimum, and (3) that the components may vary from the manufacturers' 'intended' size to a practicable oversize or undersize as a result of uncontrollable or unpredictable physical changes in the material during manufacture, expansion or contraction due to temperature or humidity, or lack of precision manufacturing machinery.

In standards of the Canadian Standards Association, the Canadian Government Specifications Board and those of trade associations, manufacturers and builders have already agreed on reasonable deviations from the intended or 'manufacture' size which are in keeping with good building practice and quality manufacturing; and through job experience manufacturers and builders know the desirable size and acceptable maximum and minimum sizes of the joints required by the various components for sound construction. Therefore, the procedure simply requires that the sum of each component and its joint never be greater than a multiple of 4 inches, even when the component varies to its maximum manufactured oversize limit and the joint is at its minimum acceptable size; nor less than a multiple of 4 inches, when the component varies to its minimum manufactured undersize limit and the joint is at its maximum acceptable size.

Modular Range of Components

It is an economic necessity for a manufacturer to produce components only in a limited range of sizes, being certain at the same time that they will readily fit other building components. Yet with this restriction a sufficient number of sizes must be provided for adequate flexibility in the arrangement of components for variation in building design. Such a limited coordinating range is possible where manufacturers agree to select sizes from a framework of modular dimensions.

For some components, all their modular dimensions will be an even multiple of 4 inches (a concrete block 8 by 8 by 16 inches), while in others only two may be modular and the third non-modular (glass thickness, a non-additive dimension). In establishing a range, not every multiple of 4 inches should be selected for a component. Instead numbers such as 4, 8, 12 and 16 at the lower end of the order of multiples are preferred since greater flexibility can be achieved with additive combinations of the smaller numbers.

The range will be further reduced by elimination of dimensions which create components of aesthetically disturbing proportions such as those which are 'almost' square, 40 by 44 inches, or too long and narrow for manufacturing or installation practicality; by components having to 'fill in' between dimensions set by building codes; or by anthropometrical dimensions, such as door, desk, and ceiling heights. For example, in Sweden door components are two modular heights, 6 feet 8 inches and 7 feet, and four widths, 2 feet 4 inches, 2 feet 8 inches, 3 feet 0 inch and 3 feet 4 inches.

Modular Dimensions on Working Drawings

Throughout the building process, dimensions of components must be transmitted between architect, contractor, manufacturer, and craftsman. To avoid confusion and error, these instructions should be simple and clear. Mistakes often result when dimensions are difficult to read because there are too many fractional numbers crowded on a small drawing, or they are awkward to enunciate, record, add and subtract. Such mistakes are particularly costly when factory-made components which cannot be corrected on the job site are used.

The transmittance of modular dimensions is clear and simple, either by feet and inches in 4-inch multiples (e.g. 2 ft-8 in. by 9 ft-4 in.) or by a certain number of the 4-inch modules (e.g. 8M by 28M).

These non-fractional numbers may be clearly shown on assembly drawings when the scale of the drawing is as small as 1/8th or 1/16th inch to the foot. Such small scale drawings are quicker to draw, as unessential, fine detail is eliminated, and complete plans of large floor areas may be shown on one convenient size sheet of paper, i.e. at 1/16th inch to the foot a floor 480 by 640 feet within 30 by 40 inches. But whether modular assembly drawings are made at the smaller scales or at 1/4 inch to the foot, modular dimensions assist building contractors to reduce errors in taking off quantities and in site assembly.

To use modular dimensions properly, however, requires a complete understanding of what they really are. They are not usually measured from the surface of components, as in non-modular drawings, but from grid lines which control the sizes of components as the basis for coordination. Therefore, there must be a description of the distance or offset between the surface of the component and the grid line to which the dimension is given.

For most components this is one-half the established assembly joint of the component. This may be done in the large scale drawing, 1½ inches to the foot or 3 inches to the foot, that is commonly prepared for contract work, or in accepted industrial modular standards. Ultimately, most common components and their assembly joints will be described in the latter manner, as is already being achieved in Scandinavian countries, so that architects, manufacturers, and all tradesmen will become familiar with them and their repetition on working drawings will be unnecessary.

In small scale assembly drawings, where it is impossible to show both the grid line and the actual surface of the component as the two may be less than a pencil line's width apart, there should be clarification of the fact that the given dimension is to a grid line, which is preferable as previously shown, or to an off-grid point. This may be done by establishing the following drawing convention. "Dimensions given to a grid line: have the dimension line terminated with an arrowhead. Dimension given to an actual surface or point not on a grid line: have the dimension line terminated with a dot."

Continual developments in technology and mechanization are providing the building industry with larger and larger building components, together with methods of putting them in place on the site. Factory-made components such as curtain-wall panels, office partition walls, precast concrete stairs, precast concrete structural floor panels, and steel framing members can be used to the best advantage by planning for them during the early stages of the design work with the aid of a 'planning grid'. This planning grid is determined by the modular size of the components being used, so that there is assurance that whole components will fit into place without alterations.

Assembly of Modular Components

Manufacturing components in modular sizes and planning their assembly on paper is of limited value unless a similar degree of precision can be achieved in field assembly. A procedure for the accurate location of components must be introduced to many trades which at present are unaccustomed to factory-like precision work. Fortunately this can be done very easily by the reference grid system.

When a building is laid out on the site, a reference grid datum point is established; from this point horizontal and vertical grid lines are measured, radiating at 4-inch intervals. Only the position of the principal grid lines shown in the assembly drawing need be measured off, as it is from these that the actual position of a component is obtained by applying a dimension which is customary for the particular component in modular construction, or which is shown on the detail working drawing.

As an aid in finding the position of grid lines, it may be convenient to have a tape, and for laying modular masonry units a story-pole, marked off in 4-inch intervals. By constantly relating components to this grid position, there is no chance of their gradually creeping out of place and causing an error in an over-all measurement. This checking permits a deviation in the size of a component to be absorbed in its own joint, rather than have them accumulate.

Conclusion

The foregoing has been a summary of what is meant by the term "modular coordination" with some indication as to how this development in measurement can be applied in manufacturing, in building design, and on the construction job. The constructive results of its application will steadily increase as its use extends. The Division of Building Research is preparing publications showing how the modular system can be applied primarily in design work. Further information will be gladly provided to those wishing to see how the system can be applied to their own work.

This is one of a series of publications being produced by the Division of Building Research of the National Research Council as a contribution toward better building in Canada. The Division has issued many publications describing the work carried out in the several fields of research for which it is responsible. A list of these publications and additional copies of this Building Digest can be obtained by writing to the Publications Section, Division of Building Research, National Research Council, Ottawa, Canada.